Overhead transmission lines

Insulators

Introduction

These guidelines describe the requirements on cap and pin insulators for insulator sets in accordance with TR 05-10E for overhead transmission lines and cover design and inspection. The guidelines intend to guarantee satisfactory performance of insulators during the lifetime of the overhead line and shall be used at purchasing of insulators.
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<thead>
<tr>
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<td>1(A)</td>
<td>New template.</td>
<td>09 / 07 / 2008</td>
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<td>New template. Clause 11.5.2.1 and 11.5.2.3 revised. Clause 11.9.2.5 revised. Rev. 11.9.2.7.</td>
<td>09 / 06 / 2016</td>
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<td>New template clause numbers changed. Clause 5.1.6 inserted. Clause 7.1 sample size revised</td>
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<td>Totally reworked</td>
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1 References

EN ISO 9001 Quality management systems – Requirements
C.I.S.P.R 16-2-1 Specification for radio disturbance and immunity measuring apparatus and methods - Part 2: Methods of measurement of disturbances and immunity
IEC/TR0 60797 Residual strength of string insulator units of glass or ceramic material for overhead lines after mechanical damage of the dielectric
EN ISO 148-1 Metallic materials - Charpy pendulum impact test - Part 1: Test method
EN 60305 Insulators for overhead lines with a nominal voltage above 1 kV - Ceramic or glass insulator units for a.c. systems - Characteristics of insulator units of the cap and pin type
EN 60372 Locking devices for ball and socket couplings of string insulator units - Dimensions and tests
EN 60383-1 Insulators for overhead lines with a nominal voltage above 1 000 V- Part 1: Ceramic or glass insulator units for a.c. systems - Definitions, test methods and acceptance criteria
EN 60383-2 Insulators for overhead lines with a nominal voltage above 1 000 V- Part 2: Insulator strings and insulator sets for a.c. systems - Definitions, test methods and acceptance criteria
EN 14647 Calcium aluminate cement-Composition, specifications and conformity criteria
IEC 61325 Insulators for overhead lines with a nominal voltage above 1 kV - Part 1: Insulators units of ceramic material or glass for d.c system-Definitions, test methods and acceptance criteria
IEC 61467 Insulators for overhead lines-Insulator strings and sets for lines with a nominal voltage greater than 1000 V-AC power arc tests
EN 60437 Radio interference test on high-voltage insulators
IEC 60120 Dimensions of ball and socket couplings of string insulator units
EN-ISO 2409 Paints and varnishes – Cross-cut test
IEC 62073 Guidance on the measurement of hydrophobicity of insulator surfaces
TR05-10E Svenska kraftnät Technical guidelines – Insulator sets

2 Scope

These guidelines describe the requirements on insulators for insulator sets in accordance with TR 05-10E for overhead transmission lines and cover design and inspection.

3 Definition

Technical terms and definitions used in these guidelines:

**Residual breaking load**
Breaking load of insulators with the shed of the insulating part cracked or completely broken off.

4 Description

4.1 Ball and socket type disc insulator
Individual insulators with the insulating part shaped as a dish made from glass with sockets shaped as into a cap and a pin with an end ball made from metal. See IEC 60305.

5 Requirements

5.1 General
Insulators shall be able to withstand the mechanical stresses which can occur during transport, handling and installation at temperatures as low as −40 °C, in addition to the mechanical stresses that can occur during the lifetime of the overhead line at temperatures from −50 °C to +100 °C.

The manufacturer shall have a quality system in accordance with at least EN ISO 9001.
5.2  Material and design of cap and pin insulators for AC and DC overhead lines

Material and design shall be in accordance with TR05-11E clause 5.1 and 5.2

5.2.1  Material and design cap and pin insulators

<table>
<thead>
<tr>
<th>Detail</th>
<th>Material</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulator</td>
<td>Toughened glass in accordance with IEC 60383-1</td>
<td>In accordance with IEC 60305</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sizes in accordance with TR05-11E clause 9.</td>
</tr>
<tr>
<td>Cap and pin</td>
<td>Hot dip malleable or spheroidal graphite cast iron for caps and forged steel for pins.</td>
<td>In accordance with IEC 60120. Size 16B shall not be used.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The impact strength of the pin shall be minimum 27J at 0°C when tested in accordance with EN ISO 148-1.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Galvanizing Zinc thickness in accordance with IEC 60383-1</td>
</tr>
<tr>
<td>Splitpin</td>
<td>Copper alloy with max 15% zinc content or austenitic stainless steel (A2).</td>
<td>In accordance with IEC 60372</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W-clips shall not be used.</td>
</tr>
<tr>
<td>Cement</td>
<td>Hot cured aluminous cement</td>
<td>In accordance with EN 14647</td>
</tr>
<tr>
<td>Cap mounting</td>
<td>No plastic rubber, or similar rings or seals are allowed to be used at the point where the cap seats on to the glass shell.</td>
<td>To ensure contact between the fitting and the glass shell. The assembly should be made with cement and flock.</td>
</tr>
<tr>
<td>Corrosion protection</td>
<td>Fog type insulators shall be equipped with zinc sleeve and 1) zinc collar.</td>
<td>In accordance with IEC 61325 clause 35.1 and 36.1</td>
</tr>
<tr>
<td>Identification of insulator unit</td>
<td>Each insulator shall be marked.</td>
<td>In accordance with EN 60383-1 clause 5 and id- number from the manufacture process.</td>
</tr>
</tbody>
</table>

1)  Only DC -insulators

6  Test program

6.1  Type test of insulators for AC and DC overhead lines

Mechanical type test reports for insulators shall not be older than 10 years in accordance with IEC 60383-1.
Type test for AC-insulators shall be performed in accordance with TR05-11E table 2 and for DC-insulators in accordance with TR05-11E table 3. The tests shall be performed on three test samples.

6.2 Sample test of insulators for AC and DC overhead lines

Sample tests shall be carried out by the manufacturer on insulators selected at random from the lot to be supplied.

Test samples shall be supplied by the manufacturer free of charge to the client and shall not be included in the lot to be supplied.

The size of the test samples are indicated in table below.

<table>
<thead>
<tr>
<th>Lot size</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td>N ≤ 300</td>
<td>1-3 subject to agreement</td>
</tr>
<tr>
<td>300 &lt; N ≤ 2000</td>
<td>4</td>
</tr>
<tr>
<td>2000 &lt; N ≤ 5000</td>
<td>8</td>
</tr>
<tr>
<td>5000 &lt; N ≤ 10000</td>
<td>12</td>
</tr>
</tbody>
</table>

The samples shall be subject to testing in accordance with TR05-11E table 2 for AC-insulators and TR05-11E table 3 for DC-insulators.

Insulators which have been submitted to test shall be discarded.

The manufacturer shall inform the client when sample tests will be performed.

Records from the sample tests shall be filed by the manufacturer and be shown to the client on request. In the case where any component does not comply with the requirements, re-testing shall be performed as below.

If only one insulator, or part thereof, fails to comply with the sample test requirement, a new sample equal to twice the quantity originally submitted for that test shall be subject to re-testing. The re-testing shall comprise the test or tests in which failure occurred.

If two or more insulators, or parts thereof, fail to comply with any of the sample tests, or if any failure occurs during re-testing, the complete lot shall be considered not to comply with the requirements.

Provided that the cause of the failure can be clearly identified, the manufacturer may sort the lot to eliminate all the insulators with this defect. The sorted lot shall then be resubmitted for sample testing. The number then selected shall be three times the first quantity chosen for the test. The re-testing shall comprise the test or tests in which failure occurred in the original test.
If any insulator, or part thereof of the sorted lot, fails during this re-testing, the complete lot shall be considered as not complying with the requirements.

6.3 Routine test of insulators for AC and DC overhead lines

Routine test for AC-insulators shall be performed in accordance with TR05-11E table 2 and for DC-insulators in accordance with TR05-11E table 3. The tests shall be performed on all insulators.
7 RTV coated insulator

7.1 Introduction
It can be necessary to install silicone coated toughened glass insulators for a shorter section in very heavy or heavy polluted areas, for example the seaside of the Swedish west coast.

This specification covers the technical requirements for RTV (Room temperature vulcanized) coated toughened glass insulators for suspension set and tension set.

7.2 General requirement
The manufacturer shall include with his offer a proof of experience in the supply of silicone coated insulators through the following evidence:

- A list of at least five projects supplied by the manufacturer giving the time of delivery, quantities supplied and full name and address of these purchasers.
- Minimum one performance certificate from recognized utilities confirming the good performance of the coated insulators after a minimum of 5 years in operation.

7.3 Technical requirement

7.3.1 Toughened glass insulators
Requirements for glass insulators see TR05-11E clause 5.

7.3.2 RTV coating

Material
The Silicone coating shall have a good tracking and erosion resistance and contain Alumina tri hydrate filler (ATH), with a minimum of 30%. The coating material should develop a high level of hydrophobicity (HC1) according to IEC TS 62073 annex D.

Application
The thickness of coating shall be in accordance with TR05-11E clause 7.4. The base of the cap shall be coated to a height of 0.5-1 cm in the zone near to the glass shell.

The application of the coating shall be made in the insulator manufacturer’s plant. The coating shall be applied through an automated process assuring the uniformity and the thickness of the coating as well as the homogeneity of the surface. The curing shall be done under well-controlled environmental conditions. The layer of
silicone shall be strongly bonded to the surface of the dielectric shell, in such way that it shall not be possible to peel it off.

The zinc sleeve of the pin and zinc collar (if present) shall not be coated with silicone.

7.4   Test program for RTV coated insulators
The silicone coating shall be applied on toughened glass insulators which have passed all the tests specified in TR05-11E clause 6. In addition, the following tests shall be carried out.

7.4.1   Type test

**Ageing test and salt fog test**
The resistance of the silicone coating to the stress of electrical discharge activity shall be verified by a multiple stresses tracking and erosion test during a period of 2000 hours. The test specimen shall include one vertical and one horizontal string of at least four coated insulator units. The cycle of stresses applied shall include alternate sequences of salt fog, humidification and rain fall while the string are submitted to high voltage stress, Up. The rain shall comply with IEC EN 60060-1 standard.

$$\text{Up}=K\times L \times 1.1$$

Where,
K is the ratio between the max system voltage of the line and leakage distance of the complete string 
L is leakage distance of the sample string.

**Acceptance criteria**
No more than three flashovers occurred and tracking or erosion of the coating layer does not reach the glass shell.

**Power arc test**
The test shall be performed on three individual RTV coated insulator strings of six insulator units type U120BP and U210BP. Each string shall be stressed by one power arc with a current of 6 kA rms and a duration of 0.2 seconds. The test arrangement shall be in accordance with IEC 61467, with unbalanced supply and return circuit, forming a D-circuit.

Afterwards each insulator string shall be completely immersed in tap water at room temperature for 42 hours. Followed by a wet power-frequency voltage test in accordance with IEC 60383-1, to each of the three insulator strings with a specified wet power-frequency voltage of 210 kV for U120BP type, and 270 kV for U210BP type.
**Acceptance criteria**
There shall not be any critical visual damage or partial or complete breakage of any shed. No flashover shall occur during the wet power-frequency tests.

**7.4.2 Sample test**
Re-test procedure in accordance with clause 8.3 of IEC 60383-1 is applicable to these tests.

**Thickness of RTV coating**
To be performed on E1 & E2.

The test shall be carried out using an ultrasonic thickness gauge.

The measurement of the thickness shall be performed in 9 different positions “Upper surface” (3x3 points at 120 degrees apart), “Bottom surface” (3x5 points at 120 degrees apart) along the surface of the glass insulator in accordance with the scheme below.

![Diagram of RTV coating thickness measurement](image)

The result is acceptable if:

The average of “Upper surface” values is above 350 µm and below 430 µm.

The average of “Bottom surface” values is above 280 µm and below 380 µm.

On other surfaces where the application of silicone coating is more difficult, the thickness can be lower but it shall be applied regularly. The measurement of the thickness is not carried out in these areas.

**Adherence test**
To be performed on E1 and E2.

The test of adherence shall be performed in accordance with EN-ISO 2409 “Paints and varnishes – Cross-cut test”. Orthogonal traces and parallel traces shall be made.
The measurements shall be performed on two opposite sides of the upper surface of
the same insulator. Acceptance level: Classification 0 and 1.

**The hydrophobicity control**
The hydrophobicity control test shall be performed according to the technical
specification IEC TS 62073-method C “Guidance on the measurement of
hydrophobicity of insulators surfaces – Spray method.

Acceptance Criteria: The result is satisfactory if the hydrophobicity class is
comprised between HC1 and HC3.

**Fail-safe, visual assessment (broken glass damage unit, self indication )**
Broken glass damage, self-indication shall be possible to see at an realistic distance
by a linesman.

### 7.4.3 Routine test

**Visual inspection**
The silicone coating shall present a homogenous aspect with smooth surface and a
uniform colour. No drops, flow marks, runnels, bubbles nor accumulation of
silicone shall appear at surface.

# 8 Delivery

## 8.1 Documentation

### 8.1.1 General
All documentation shall be written in English.

Complete documentation in accordance with clauses 8.1.2 – 8.1.5 shall be available
to the client before delivery.

### 8.1.2 Assembly drawing
The assembly drawing shall have a minimum of two views at an appropriate scale.
On the drawing shall be given:

- Type and/or Catalogue number
- Principal dimensions
- Failing load
- Electrical data
- Creepage distance
- All marking
• Weight
• List of materials

8.1.3 List of material
Description of material in included parts. Preferably described on the assembly drawing.

8.1.4 Installation instruction
Installation instructions in English with required drawings to prevent handling damage during installation for example for RTV coated insulators.

8.1.5 Reports
Complete reports with all measured values reported, from all controls according to TR05-11E clause 6 and clause 7.4.

8.1.6 Packing and palletization
Factory assembled strings of insulators shall be packed using a protective polyurethane packing foam or similar in wooden crates, which are held closed by external steel band/plastic band. Crates shall be evenly stacked on a sturdy four-way wooden pallet. The assembly shall be held tightly in place with either steel or plastic bands and protected against moisture by a complete covering of polyethylene film. The pallet shall have an identification label with tracking information from the manufacture process. A packing list shall be provided with the delivery.
9 Tables

Design dimension of cap and pin insulators to be used in Svenska kraftnät insulator sets. Specified values mechanical and dimensional characteristics for string insulator units with ball and socket couplings in accordance with IEC 60305.

Table 1A Standard profile, cap and pin insulators, normal creepage

<table>
<thead>
<tr>
<th>Designation</th>
<th>U70BL</th>
<th>U120B</th>
<th>U210B</th>
<th>U300B</th>
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<tr>
<td>Max. nominal diameter of insulator disc</td>
<td>mm</td>
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<td>Nominal spacing length</td>
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<td>Min. nominal creepage distance</td>
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<td>kN</td>
<td>kN</td>
<td>kN</td>
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Table 1B Fog type profile, cap and pin insulators, extended creepage

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<th>U70BLP</th>
<th>U120BP</th>
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<td>Sample test</td>
<td>Routine test</td>
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<td>Zinc Sleeve or collar</td>
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<td>IEC 60383-1 clause 13</td>
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<td>Wet power-frequency voltage test</td>
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<td>IEC 60383-1 clause 14, IEC 60383-2</td>
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<td>C.I.S.P.R 16-2-1, 20 kV</td>
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Routine visual inspection

<table>
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<th>IEC 60383-1 clause 27</th>
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<tbody>
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<td>Every insulator unit</td>
<td></td>
<td></td>
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</table>

Routine mechanical test on string insulator units

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>IEC 60383-1 clause 2.2</th>
<th>IEC 60383-1 clause 28.2</th>
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</thead>
<tbody>
<tr>
<td>Every insulator unit</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SFL = Specified Mechanical Failing load

**Radio interference test**

The test shall, on cap & pin insulators, be performed with 20 kV 50 Hz alternating current (r.m.s. value) over 1 *V interference voltage and 500 kHz measuring frequency at test in accordance with C.I.S.P.R 16-2-1 and SS-EN 60437.

From the individual interference levels X measured at the test shall the mean value Xm and the standard deviation σn-1 be calculated.

where

\[ X_{20} = \text{mean value of the lot at } 20 \text{ kV [dB]} \]

\[ \sigma_{20} = \text{standard deviation of the lot at } 20 \text{ kV [dB]} \]

\[ C_{20} = \text{acceptance level at } 20 \text{ kV} \]
<table>
<thead>
<tr>
<th>Test</th>
<th>Type test</th>
<th>Sample test</th>
<th>Routine test</th>
<th>Standard</th>
<th>Acceptance criteria</th>
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<tr>
<td>Dimensions</td>
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<td>IEC 1325 clause 22</td>
<td>IEC 1325 clause 22, Spacing IEC 60305 clause 5</td>
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<td>Displacements</td>
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<td></td>
<td>IEC 1325 clause 27</td>
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<td>IEC 1325 clause 28</td>
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<td>Temperature cycle test</td>
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<tr>
<td>Mechanical failing load</td>
<td>X</td>
<td>X</td>
<td></td>
<td>IEC 1325 clause 24</td>
<td>IEC 1325 clause 23.2, Individual value ≥SFL, and C1=3</td>
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<tr>
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<td>IEC 1325 clause 26</td>
<td>IEC 1325 clause 26, The constant $k$ should be ≥0.80</td>
</tr>
<tr>
<td>Body resistance test</td>
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<td></td>
<td>IEC 61325 clause 19</td>
<td>Result similar value given in type test report and &gt; 10GΩ at 90°C</td>
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<tr>
<td>Impulse overvoltage puncture withstand test</td>
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<td>IEC 1325 clause 17</td>
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<td>Thermal chock test</td>
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<td>IEC 1325 clause 30</td>
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<td>Zinc sleeve test</td>
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<td>IEC 1325 clause 35.3</td>
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<td>Zinc collar test</td>
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<td>IEC 1325 clause 36</td>
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<tr>
<td>Galvanization test</td>
<td>X</td>
<td>X</td>
<td></td>
<td>IEC 1325 clause 32</td>
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<tr>
<td>Radio interference</td>
<td>X</td>
<td></td>
<td></td>
<td>C.I.S.P.R 16-2-1, 20 kV</td>
<td>See below</td>
</tr>
</tbody>
</table>
Routine visual inspection | X | IEC 1325 clause 33 Every insulator unit | IEC 1325 clause 33

Routine mechanical test on string insulator units | X | IEC 1325 clause 34 Every insulator unit | IEC 1325 clause 34

SFL= Specified Mechanical Failing load

**Radio interference test**

The test shall, on cap & pin insulators, be performed with 20 kV 50 Hz alternating current (r.m.s. value) over 1 *V interference voltage and 500 kHz measuring frequency at test in accordance with C.I.S.P.R 16-2-1 and SS-EN 60437.

From the individual interference levels $X$ measured at the test shall the mean value $X_m$ and the standard deviation $\sigma_{n-1}$ be calculated.

where

$X_{20} =$ mean value of the lot at 20 kV [dB]

$\sigma_{20} =$ standard deviation of the lot at 20 kV [dB]

$C_{20} =$ acceptance level at 20 kV